HYDROLOGIC CHARACTERIZATION OF THE KARST AQUIFER -- ANTIETAM NATIONAL BATTLEFIELD

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science for a changing world

Antietam National Battlefield

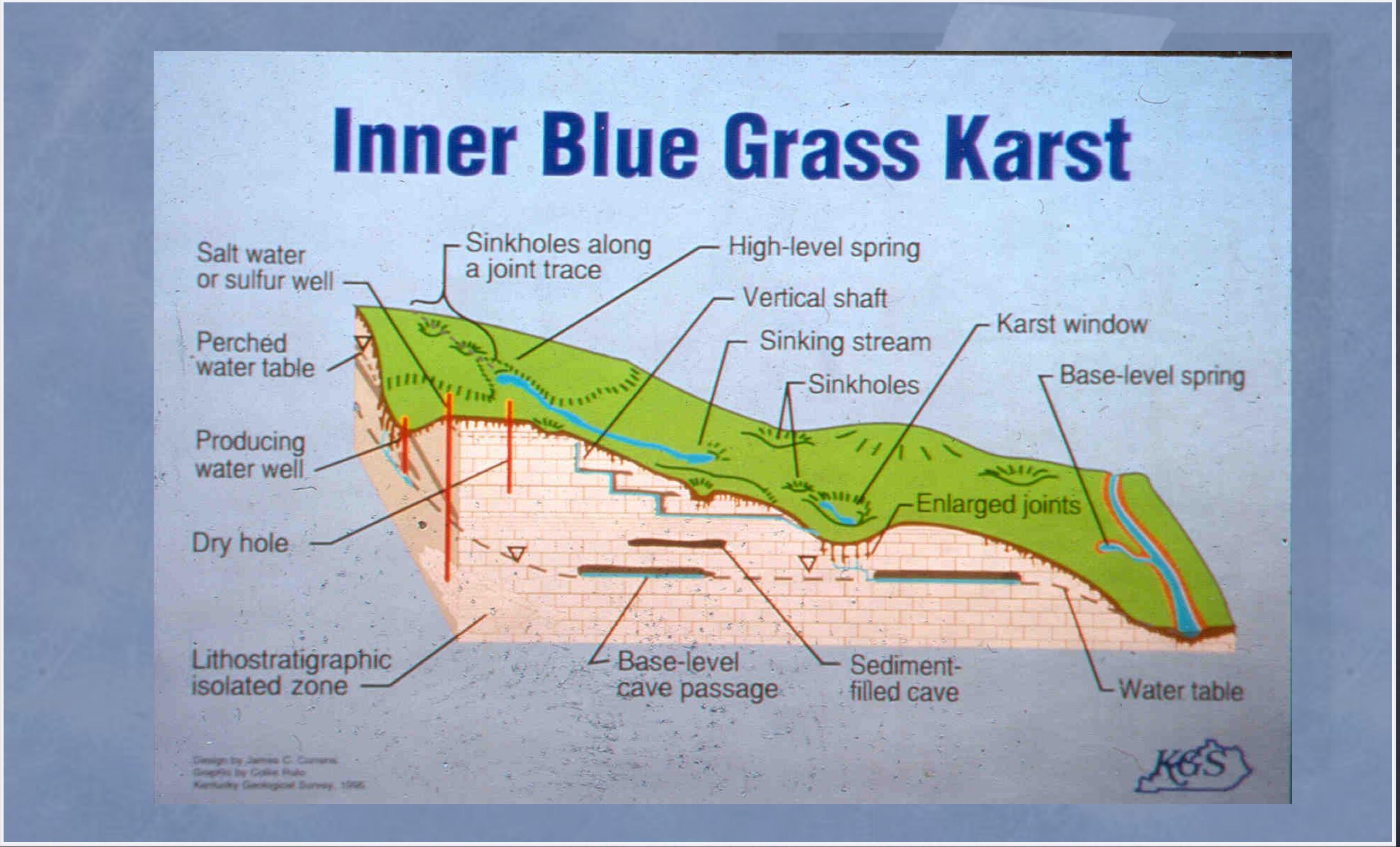
GEOLOGY - karst

- Type of terrain
- Formed on carbonate rock (limestone and dolomite)
- Ground water flows through solutionally- enlarged openings to form a subsurface drainage system
- As flow routes enlarge the aquifers change from a diffuse-flow aquifer with water moving through small openings to a conduit-flow aquifer with water moving through a well-developed system to discharge points (SPRINGS)

Karst Evolution

- As the water table lowers below the level of the surface streams, the streams start to lose water to the developing cave systems.
- As more of the surface drainage is diverted underground stream valleys disappear and replaced by closed basins called sinkholes.
- Sinkholes vary from small cylindrical pits to large conical basins that collect and funnel runoff into the karst aquifer.

Single Level Conduit System



Quantitative Analysis

- Conceptualized as integrated underground trunk streams that discharge at the basin outlet (spring)
- Spring hydrographs display the response of the karst hydrologic system to recharge events (storms)
- By analyzing the spring hydrograph it is possible to determine the average of “basin” hydraulic properties

Ground Water Flow in a Karst Aquifer

Continuum

DIFFUSE	MIXED	CONDUIT
(POROUS MEDIA)		(CAVE DOMINATED)

Flume - To Measure Springflow

Spring-Discharge Recession Governing Equation

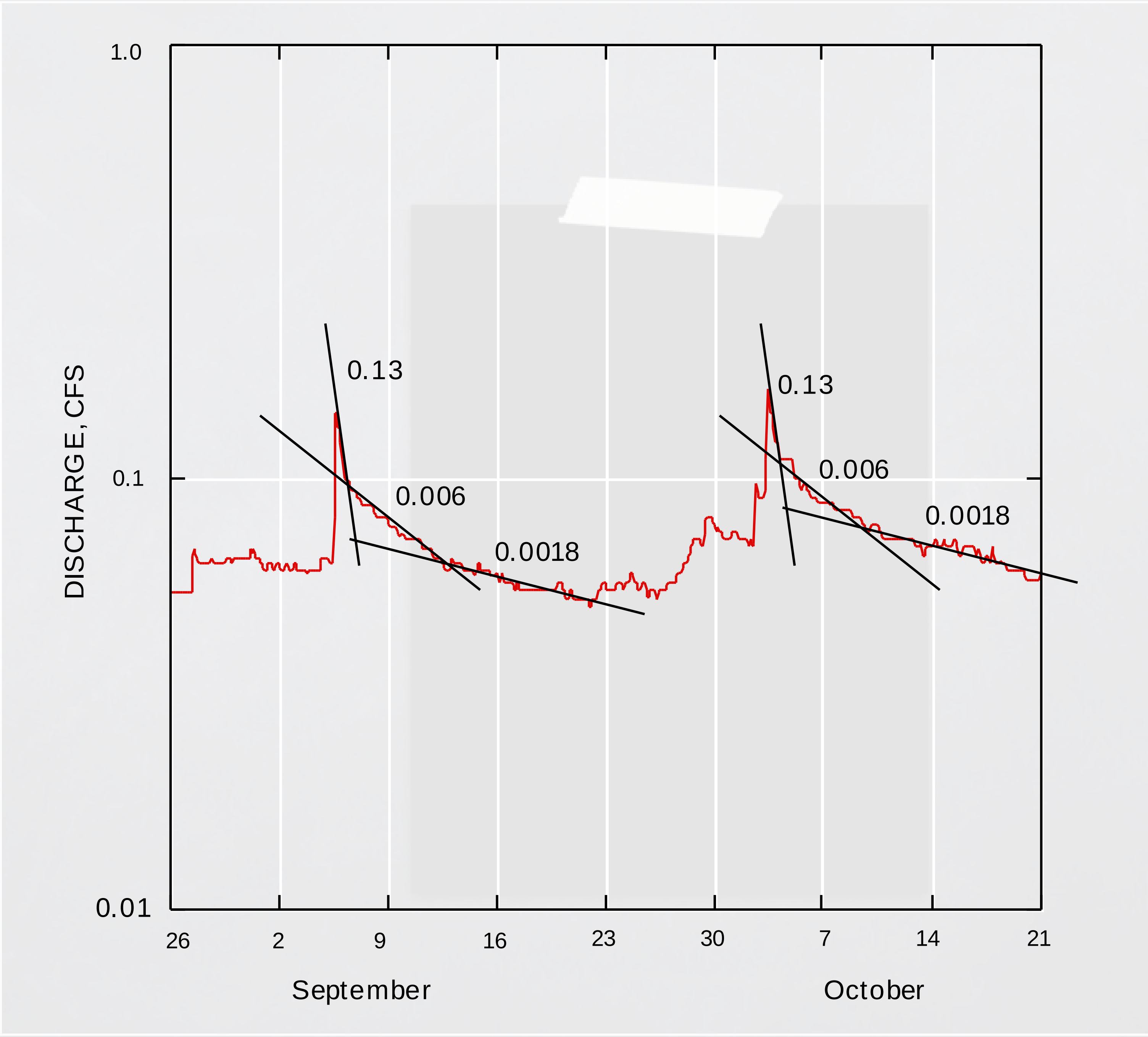
$$Q_t = Q_o^{e^{-\alpha t}}$$

Mumma Spring Flow Regimes

- 3 - components of karst flow
  - conduit
  - mixed
  - diffuse
- Recession Constants

  α

  - 0.13
  - 0.006
  - 0.0018



Contributing Area to Mumma Spring

- Linear Systems Analysis -- 3 equations
- Connection can be made between the active area (A) of the aquifer, aquifer volume (V), and recession constants α

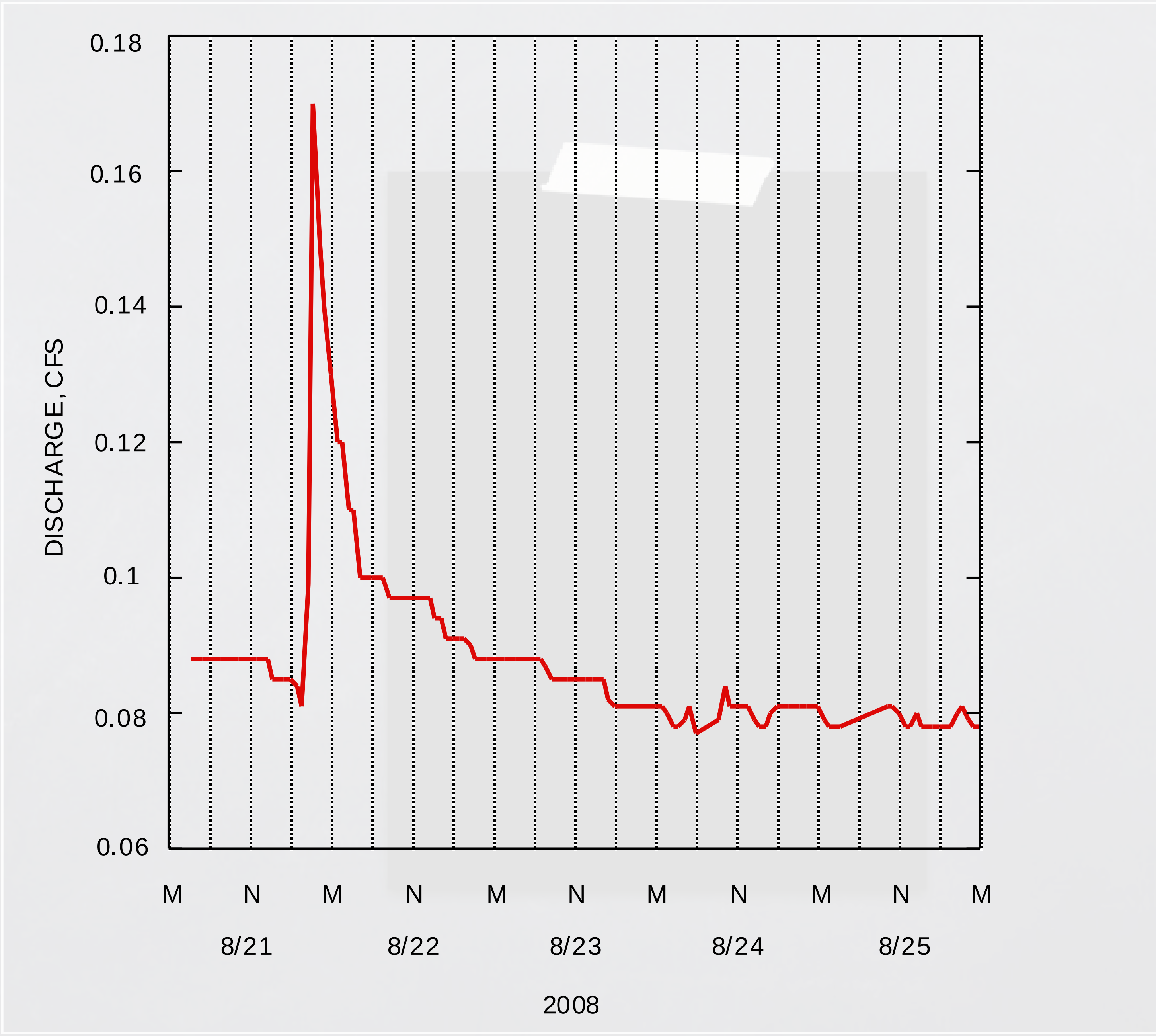
$$\alpha = \frac{\lambda}{A}$$

$$Q = \frac{V}{\alpha}$$

$$\alpha = \frac{1}{j}$$

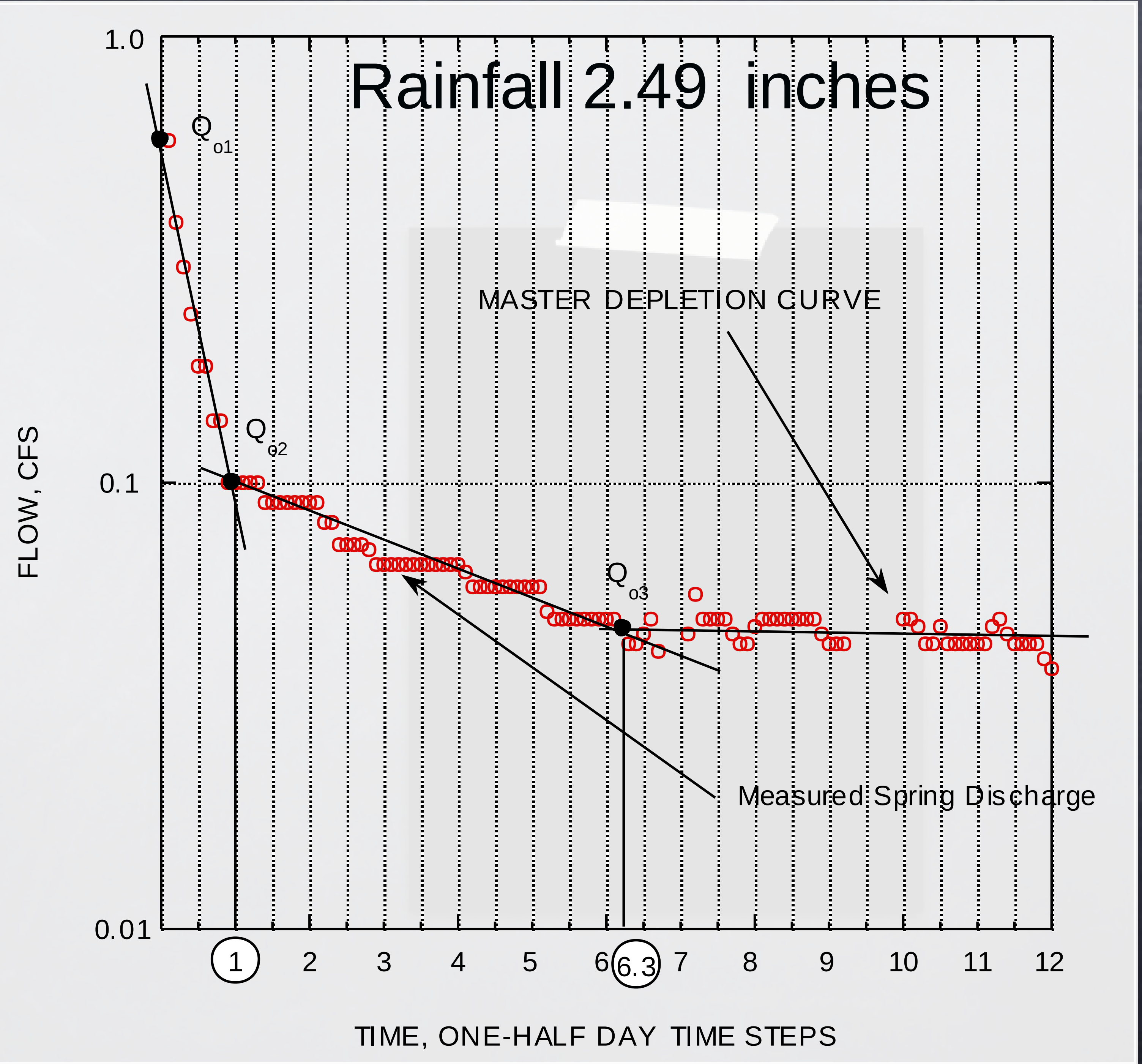
Mumma Spring Storm Response

- High intensity - 2.49 inches
- Aug 21-22, 2008
- Discharge rose to 0.17 cfs in response to the storm
- Discharge fell to about 0.08 cfs which is the baseflow of the karst system



Master Depletion Curve

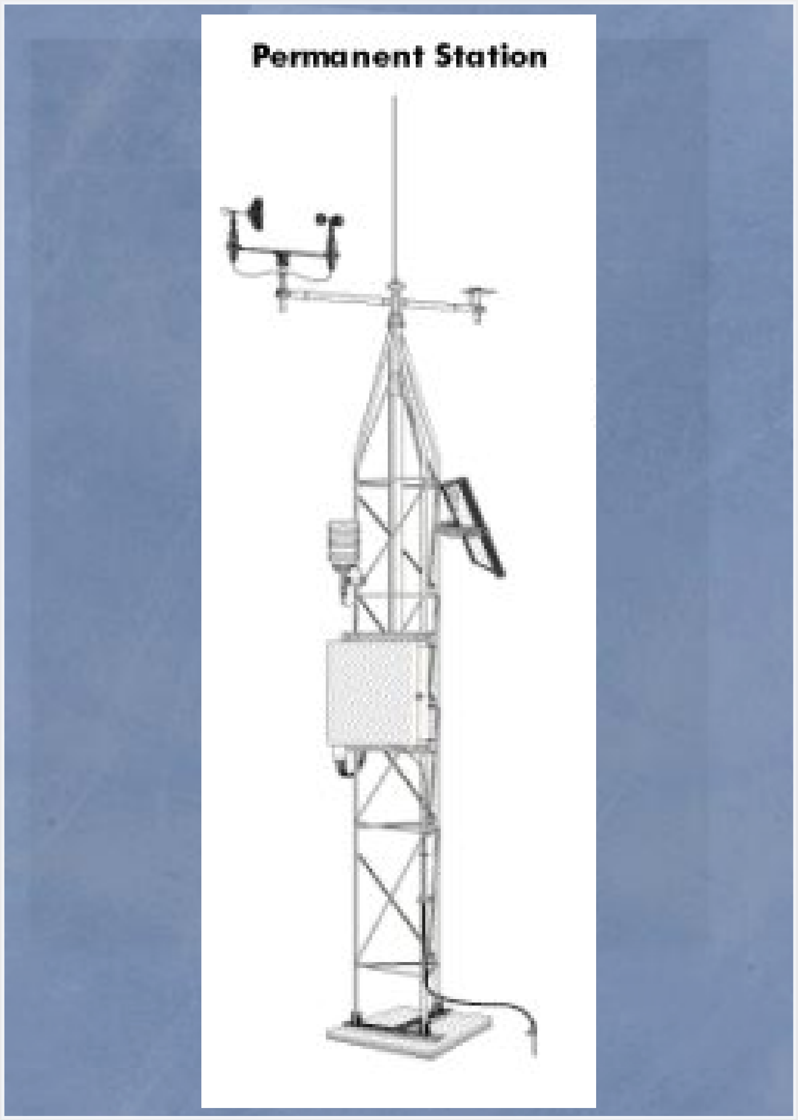
- Break Points
- Decrease in effective Basin Area and Volume
- 1-day emptying of conduits
- 6.3-days all flow is diffuse



Mumma “Simulated” Spring Discharge

- Assumes discharge is non-stationary and is driven by precipitation (storm events)
- Dependent on contributing area of the aquifer
- Synthetic Hydrograph

Continuous Precipiation Monitoring



Governing Equations

Q is discharge at any time, t

$$Q_{1t} = f_1\left[1-\exp\left(-\frac{t}{j}\right)\right]$$

j is the reservoir coefficient

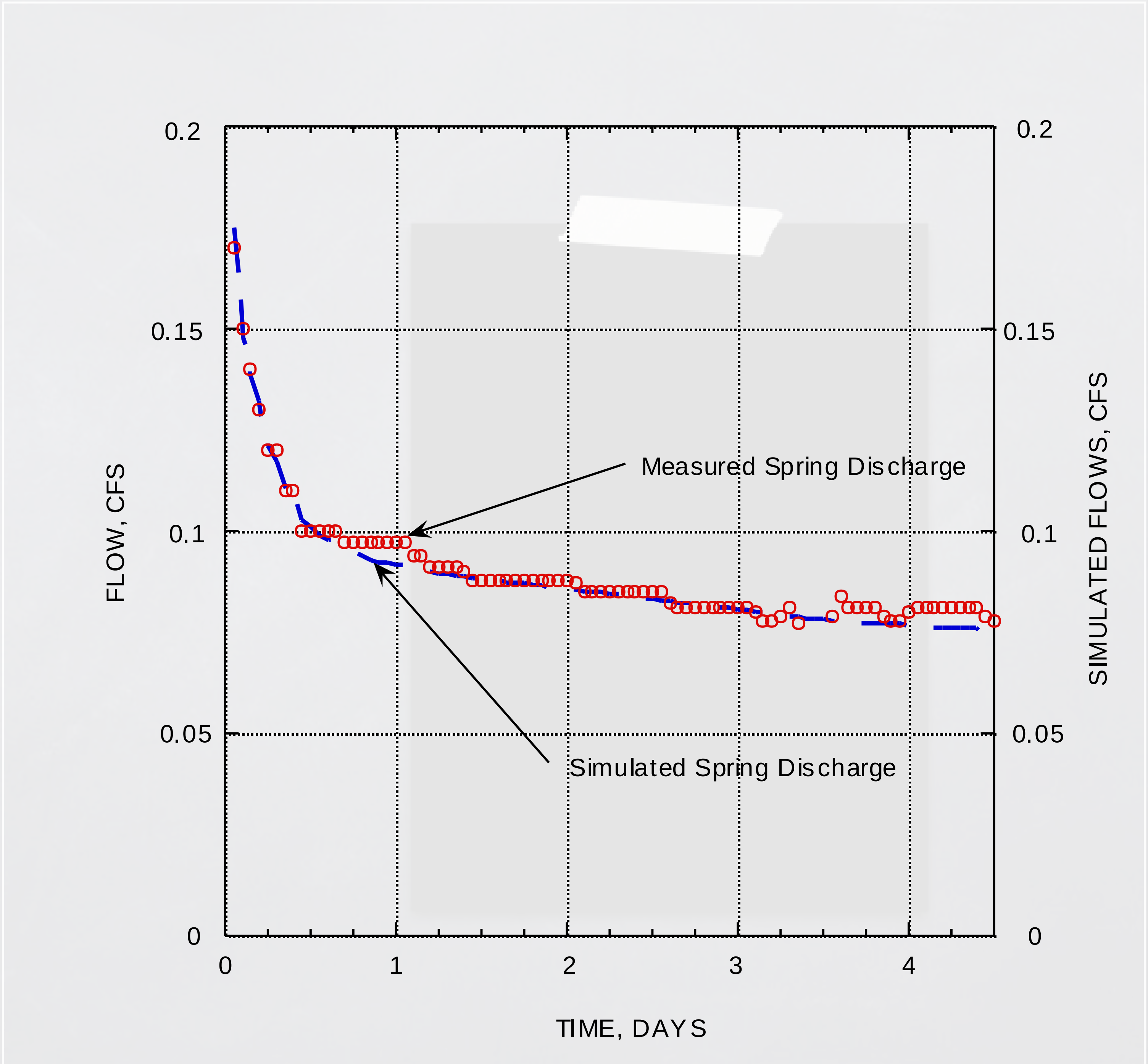
$$Q_{1t} = f_1\left[1-\exp\left(-\frac{t}{j}\right)\right] + Q_{(i-1)t}\exp\left(-\frac{t}{j}\right)$$

input function driving the karst spring

$$f_1 = P_i - ET_i - SM_i$$

Mumma Spring Sumulated Flows

- High intensity rainfall - 2.49 inches
- Aug 21-22, 2008
- Robust fit



Simulated aquifer drainage areas contributing flow to Mumma Spring for each of three flow regimes.

Area, sq miles	Governing Equation	Prevailing Flow Regime
~ 0.7	$\phi \leq t \leq 1.0$ and $Q_t = Q_{o1} e^{-\alpha_1^t}$	Conduit
~ 0.8	$1.0 \leq t \leq 6.3$ and $Q_t = Q_{o2} e^{-\alpha_2^t}$	Mixed Flow
~ 1.0	$6.3 \leq t \leq \alpha$ and $Q_t = Q_{o3} e^{-\alpha_3^t}$	Diffuse

Summary & Conclusions

- Spring-discharge analysis at Mumma Spring has identified the karst flow regimes
- Determine the basin area contributing flow to the spring
- Water-level monitoring has determine dthe base level of of karst aquifer
- Can develop simulated response hydrograph for springflow using measured precipitation at the Park
- Need to tie Water Levels into the analysis